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CARBON DIOXIDE – A POTENTIALLY EXPLOSIVE SMOULDERING SILO FIRE SUPPRESSANT

As counter-intuitive as it may sound, there are explosion hazards associated with releasing liquid carbon dioxide (CO₂) into environments where an ignitable atmosphere may exist. For instance when attempting to suppress a smouldering fire in a pellet silo. A recent paper by Dr Frank Huess Hedlund, Risk Expert at Danish engineering consultants Cowi and External Associate Professor at the Technical University of Denmark (DTU), explains why CO₂ is a safe inert purge gas but may be unsafe for inerting.

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and bioenergy, the paper “Carbon dioxide not suitable for extinguishment of smoldering silo fires: static electricity may cause silo explosion” examines an explosion in a Norwegian wood pellet silo that occurred in 2010 when attempting to suppress a smouldering fire with carbon dioxide (CO₂). In the paper, the case is made that the electrostatic hazard of CO₂ is widely underappreciated and that incidents like this are avoidable.

Smouldering fires – a challenge

Smouldering fires in wood pellet storages can occur for a number of reasons. Pellets can self-heat deep inside a pile, mechanical friction can heat and ignite dust particles, and embers can travel in the conveyor system and start fires in storage areas.

Fighting a smouldering silo fire is a long and difficult activity. Often water cannot be used because wetting wood pellets causes the pellets to swell. This swelling of

wood pellets can produce forces that break silo walls, or simply because applying water to a hot spot located somewhere deep inside a large pile of material is extremely difficult. Alternative firefighting strategies have been devised which use injection of inert gases. Inert gases can deplete the oxygen available for combustion and quench the pyrolysis process. Nitrogen (N₂) and CO₂ are the most commonly used inert gases as both are readily available in large quantities.

Electrostatic hazard

However, the paper demonstrates through example and examination that the injection of CO₂ is potentially unsafe as the pyrolysis gases produced by smoldering fires may be in the ignitable range. If high-pressure CO₂ is released, static electricity may ignite the vapours, leading to a silo explosion.

Applicable standards and difficulties

The paper also examines major standards, guidelines, recent editions of frequently cited pellet handbooks, and other literature as per their mid-2016 versions. It presents examples where the static hazard is not stated; where the standard, guideline or recommended practice gives potentially ill-advised recommendations; and where the absence of warning may have serious consequences.

The situation appears particularly serious for NFPA 12: Standard on carbon dioxide extinguishing systems, which gives ill-conceived advice on the application of CO₂ to deep-seated fires involving solids subject to smouldering. NFPA 69 and NFPA 850 should also be revised to highlight the hazard.

Confusing terminology

Part of the problem appears to be a lack of precision in terminology. The usage of the terms “purging” and “inerting” is not entirely unambiguous in for instance NFPA 69 on explosion prevention systems. This is a serious shortcoming.

Carbon dioxide may be a suitable “inert purge gas” because purging, by definition, ensures that an ignit-

able mixture never forms. The introduction of a possible source of ignition due to electrostatic discharges is of no concern, in theory at least.

But purging should not be confused with inerting where an ignitable mixture of flammable gas and air is made safe by adding an inert gas. CO₂ appears to be unsuitable for this purpose due to the high chance of electrostatic ignition.

Another major issue is lack of clarity in the meaning of the terms fire and extinguishment, which are not defined in for example the NFPA 12 terminology section. The application of CO₂ is excellent for extinguishing a fire with flames, but unsuitable for quenching deep-seated smouldering fires without a flame.

Past lessons forgotten

In the past, disastrous explosions have taken place because CO₂ was released into confinements where an ignitable atmosphere was present. Lamentably, there is evidence of de-learning. That important information on the hazards, learned the hard way through investigation of past accidents, has passed out of sight. This appears to have happened in the fast growing wood pellet sector.

Recommendations

Fighting smouldering fires in wood pellet storage silos is an inherently difficult operation. The paper demonstrates the potentially disastrous consequences of electrostatic ignition from using CO₂ extinguishers to inject gases into the potentially flammable mixture in the silo headspace.

The basis of knowledge is currently insufficient to suggest an alternative “best” strategy although inerting with nitrogen seems to be the best option. Further review, testing, and partial rewording of applicable standards and guidelines are required to determine the best possible method to extinguish smouldering fires, with a reduced risk of causing a silo explosion.

The use of the following terminology related to fighting smouldering fires in wood pellet storage bins is useful.



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Flammability limits

A cloud of combustible dust or a flammable gas is able to propagate a flame, that is “explode” only if mixed with air in the right proportions. The ignitable range is defined by the lower and upper flammable or explosive limits. The limits are determined experimentally and depend to some extent on the type of apparatus used.

Limit flame temperature

A flame cannot exist below a limiting flame temperature. This concept can help explain several phenomena:

First, the effect of increasing the concentration of a non-combustible component for instance an inert gas can be understood by viewing the inert gas as thermal ballast that quenches the flame temperature to a level below the limit flame temperature.

In this regard, CO₂ is a more effective inert gas than nitrogen due to its higher molar heat capacity. Some active explosion protection systems employ early detection of an explosion followed by rapid injection of an inert solid to quench the flame before damaging overpressures are produced.

Second, a similar quenching effect can be achieved if the flame is cooled by passing through a metal mesh. This is the main principle of a flame arrestor.

Lastly, as the temperature increases, the ignitable range widens because less combustion energy needs to be released to achieve the limiting flame temperature.

Oxygen deficient smouldering fire

Combustion can also take place outside the ignitable range. For example, flammable gases can undergo slow oxidation in the presence of a catalyst. Oxygen deficient fires, deep inside a pile of solid material, a smouldering fire can exist at very low oxygen levels and, somewhat counter-intuitively, the combustion zone can move downwards, typically towards an air inlet.

Pyrolysis gases

Oxygen deficient smouldering fires generate pyrolysis gases rich in, toxic and flammable carbon monoxide (CO). This flammable gas can travel, accumulate, and create an explosive atmosphere in the

headspace of a silo.

Carbon monoxide also has an unusually wide ignitable range of 12.5 – 74 vol%. Therefore, mixtures of pyrolysis gases and air are therefore often in the ignitable range. This range further widens as the temperature increases, making the gases even more likely to explode in the presence of an ignition source.

Inerting

An ignitable mixture can be made oxygen deficient by introducing enough non-combustible (inert) gas to make the mixture non-ignitable.

Purging

A system containing air can be made safe by introducing enough non-combustible (inert) gas so that when flammable gas is introduced, an ignitable mixture cannot form. This is known as “purge-into-service” in NFPA 56.

Likewise, a system that contains a flammable gas can be made safe by introducing enough inert gas so that when air is introduced, an ignitable mixture is not created. This is known as “purge-out-of-service” in NFPA 56.

Careful use of terminology

As discussed, care needs to be taken when using terms. An inert gas injection procedure that laxly refers to simply “inerting”, because an inert gas is involved, is most unfortunate and a potential hazard – carbon dioxide is a safe inert purge gas but may be unsafe for inerting.

Some British texts (e.g. Trevor Kletz), refers to both purge procedures as “sweeping”, or “flushing”, with inert gas. In German texts, the purge procedures are referred to as “partial” and “total” inerting. The German terms clearly convey the message that purge-out-of-service requires much more agent than purge-into-service although the choice of the term “inerting” is poor.

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Editor's note: this is an edited version of an article by Dr Frank Hues Hedlund that was first published on www.mydustexplosionresearch.com, a community around dust explosion prevention, protection, and research initiated and run by Chris Cloney, Dalhousie University in Nova Scotia, Canada. It is used with kind permission.

Novel crusher to enable automatic briquette-to-boiler feed



Wood briquettes have several advantages; they can be produced easily, flexibly and inexpensively with modern machinery precisely where wood residues occur. However, a disadvantage is that small-scale biomass boilers typically used in residential and light commercial space applications cannot be fed continuously and automatically with briquettes. This has a limiting effect on the potential local market for the producer.

German briquetting machine specialists RUF GmbH, along with DBFZ in Leipzig, started a joint project to resolve this issue. According to Andreas Jessberger, Sales Manager at RUF, the advantages of the briquettes – namely cheap, flexible production – need to be combined with the advantage of pellets – good conveying characteristics. Thus the task of the innovative project was two-fold. Firstly, to find out how continuous briquette combustion can be achieved and whether there were already marketable solutions for this. Secondly, to look at the emissions occurring during combustion and, if necessary, optimize.

Slow speed twin shaft crusher

Through extensive product and patent research, DBFZ discovered that there is currently no automatic, continuous feeding of wood briquettes for a small-scale furnace. There is a patent, which describes the irregular, requirement-oriented feeding of wood-fuelled boilers with paraffined wood briquettes thus reason enough to start the project.

– First of all we must crush our RUF briquettes to implement our idea so that they can be conveyed evenly and automatically by means of a screw, said Jessberger.

A prototype briquette crusher developed by RUF engineers accomplishes this task. According to the manufacturer, the briquettes used for feeding the machine have a fuel value 5.0 kWh/kg, the cross-section is rectangular (15.3 cm × 6.3 cm) and the height is 9 cm.

The crusher consists of two electrically driven counter-rotating slow speed drive shafts, which are located inside the machine. Toothed rings are located on the opposite side of the drive shafts and have been welded in a staggered form. These have a dual function to grip and crush the briquettes that have fed into the crusher by a conveyor. A small Siemens SPC is used to monitor the drive unit

The crushed fuel falls into a storage vessel, which is monitored by filling level sensors. From the storage unit, the fuel is transferred into the small-scale boiler via a screw auger. A “C0” model ÖkoTherm boiler from A.P. Bioenergietechnik GmbH with a nominal output of 49 kW was used as the combustion unit in the showcase RUF-DBFZ project.

Classifying the emissions that occur during the combustion of the crushed wood briquettes was the second task of the project and was carried out at the DBFZ's site in Leipzig. Results suggest that average carbon monoxide (CO) emissions were below statutory framework of 0.4 g/m³ whereas dust emissions were slightly higher than the 0.02 g/m³ limit. However, additional tests are needed as there are indications that the fine particle fraction from the crushing of the briquettes is partly responsible. If confirmed, separation units on the crusher could provide a cost-efficient remedy.

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